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ABSTRACT

The model of sentence perception proposed by Fodor, Bever and Garrett (1974) emphasizes the importance of grammatical cues signalling clause boundaries, and suggests that segmentation of a sentence into clauses precedes computation of the internal structure of those clauses. However, this model has nothing to say about the many sentences in which clause boundaries are not explicitly marked, and which are therefore more difficult to parse. It is proposed that in such cases clause boundary assignment does presuppose prior analysis of sub-clausal constituents, and that parsing is guided by the strategy called in this paper "late closure." This strategy indicates that, when possible, incoming constituents are to be added into the clause being parsed. A grammaticality judgment experiment using rapid serial visual presentation confirms this theory. (Author/AM)

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VISUAL PERCEPTION OF SENTENCES WITH TEMPORARILY AMBIGUOUS CLAUSE BOUNDARIES*

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It is currently believed that clauses play a crucial role in sentence perception. For instance, in The Psychology of Language Fodor, Bever and Garrett cite a number of experiments which they say "suggest that the boundaries between clauses have a unique and characteristic role in the perceptual organization of sentences, a role compatible with the view that they mark the boundaries of the perceptual units in terms of which the sentence is analyzed." Thus, Fodor, Bever and Garrett state that clauses are the major units of sentence perception and though they do not say so explicitly, it seems that we are to understand that clausal segmentation occurs prior to the computation of the internal structure of a clause. I will refer to this view as the clause-first model of sentence perception.

Grammatical markers which signal clause boundaries clearly play an important role in this model since such markers facilitate the clausal segmentation of a sentence. (Here I assume, as do Fodor, et al., that prosody is not always by itself sufficient to determine the clausal segmentation of a sentence - see, eg. Wingfield and Klein, 1971.) But, as Fodor, Bever and Garrett fully realize, this can not be the whole story since the clause-first model does not specify how clauses are identified in a large range of sentences, such as (1), where the clause boundaries are

(1) Sylvia never likes the poems people send her.

not explicitly marked.

Clearly the parser does not simply break down when it encounters these sentences. Of course, clause boundary assignment might proceed randomly in these cases, but for a model in which the clause is the perceptual unit for purposes of later computations, random errors in the

identification of clause boundaries would surely be extremely disruptive. On the other hand, clause boundary assignment could proceed systematically if the parser either computes all possible analyses of a sentence in parallel, or if the parser relies on some parsing strategy to guide its decision about clause boundary assignment.

The assymetries observed in garden-path sentences like (2) suggest that all possible analyses of a sentence are not computed

(2a) The child kicked the ball fell over.
(2b) The child kicked the ball and fell over.

simultaneously. If they were, (2b) should ?garden-path readers and hearers just as often as (2a), which it does not. It appears, then, that the parser relies on some guessing principles or parsing strategy to guide its analysis of sentences in which clause boundaries are not explicitly marked. The parser might guess, for instance, that a clause boundary occurs immediately after the occurrence of all obligatory constituents. Following Kimball (1973), I will refer to this strategy as Early Closure. Early Closure tells the parser to close a clause as soon as possible (ie. given the well-formedness rules of the language). In contrast, the parser might guess that a clause boundary does not occur until after the occurrence of all obligatory and optional constituents. I will refer to this strategy, which tells the parser to close a clause as late as possible, as Late Closure.

Intuitions that sentences like (3a) are often misanalyzed, while

(3a) While Mary was mending the sock fell off her lap.
(3b) While Mary was mending the sock it fell off her lap.

sentences like (3b) are not, suggest that it is actually Late Closure

which governs clause boundary assignment.

So far I have argued from intuitive evidence that a parallel processing hypothesis is not consistent with the assymetries observed in garden-path sentences, and that Early Closure is not consistent with the direction of the observed assymetries. My conclusion is that Late Closure governs clausal segmentation of sentences in which clause boundaries are not explicitly marked. I turn now to experimental evidence which supports this conclusion.

Forster (1970) has shown that rapid serial visual presentation, which puts subjects under time pressure so that errors of analysis occur even for sentences which normally can be parsed correctly, can be used to assess the complexity of processing sentences. A grammaticality judgment experiment using rapid serial visual presentation was designed in order to test the predictions of Late Closure. Twenty-one pairs of sentences matched as in (3a) and (3b) were constructed with temporarily ambiguous clause boundaries. The early-closure version of each sentence (for example, (3a)) was constructed so that the actual clause boundary was followed by a potential clause boundary. The late-closure version of each sentence (for example, (3b)) was constructed so that the actual clause boundary was preceded by a potential clause boundary. A semantic-control version of each sentence was constructed so that the actual clause boundary was followed by a syntactically possible but semantically implausible clause boundary. Semantic-control sentences were included in the experiment in order to determine whether semantic information affects the parser's decisions about clause boundaries. However, semantic-control sentences will not be discussed here, since this question lies outside the scope of the present paper.

The parallel processing hypothesis predicts that early-closure

and late-closure sentences should be equally difficult to parse. Early Closure predicts that late-closure sentences should be relatively difficult to parse because the parser's first decision, to close the clause as soon as possible, will turn out to have been incorrect. For early-closure sentences it will of course turn out to have been correct, and so such sentences are predicted to be relatively easy to parse. By similar reasoning, the Late Closure hypothesis predicts that late-closure sentences should be easier to parse than early-closure sentences.

In order to vary the experimental materials and insure the generality of the experimental results, five sentence-types (A-E) were used, as shown in Table 1. Disambiguation of the temporarily ambiguous portion of a sentence was due to different syntactic facts in each of the five types of examples. There were six tokeens of sentence-types A and B, and three tokens of sentance-types C-E. Since the subjects' task was to discriminate between grammatical and ungrammatical sentences, these grammatical sentences were interspersed with ungrammatical sentences. The latter were of four types: sentences with an extra constituent, sentences missing an obligatory constituent, sentences with selection restriction violations, and sentences with subject-verb agreement violations. Each subject saw only one member of each matched triple of experimental sentences, and all 16 of the ungrammatical filler sentences. Sentences were presented one word at a time, on a cathode ray screen under computer control. Each word appeared on the screen for a duration of 300 msec. The 15 subjects were instructed to press a 'YES' button after each grammatical sentence and to press a 'NO' button after each ungrammatical sentence. A brief practice session preceded the actual experiment.

A1a. Though George kept on reading the story still bothered him.
1b. Though George kept on reading the kids still bothered him.
1c. Though George kept on reading the story Sue bothered him.

B1a. Without her contributions would be very inadequate.
1b. Without her Antarctica would be very lonely.
1c. Without her contributions the funds are inadequate.

C1a. In this race to touch the wire is to die.
1b. In this race to make a mistake is to die.
1c. In this race to touch the wire she will win.

D1a. Mary kissed John and his brother started to laugh.
1b. Mary kissed John and the car hit a tree.
1c. Mary kissed John and his brother when she left.

E1a. Anne was watching you were laughing and nobody knew why.
1b. Anne was watching sirens were blaring and nobody knew why.
1c. Anne was watching you she laughed and nobody knew why.

A-E = sentence-type categories
a = early-closure version
b = semantic-control version
c = late-closure version

TABLE 1. EXPERIMENTAL SENTENCES.

	EARLY-CLOSURE	SEMANTIC-CONTROL	LATE-CLOSURE
A	1545 msec.	1279 msec.	1160 msec.
B	1985	1397	973
C	2306	1669	1612
D	1667	1250	1065
E	1598	1059	1037
	1820	1330	1169

TABLE 2. Mean RT for correct responses.

The results of this experiment are presented in Table 2. They show that the reaction time (RT) for correct responses to late-closure sentences are systematically shorter than for either early-closure or semantic-control sentences. The difference between early-closure and late-closure sentences is not significant within each sentence-type category (A-E), however if RTs are summed across these categories the overall difference between closure-types is significant at $p<.01$ according to a two-way analysis of variance. Mean RT is given by sentence-type category in Table 2. Table 2 (and the above analysis) excludes sentences D3 and E3. Sentence D3 had to be excluded because it was discovered that the late-closure version of D3 was not a late-closure sentence at all. That is, it would have been misanalyzed by the Late Closure strategy. Sentence E3 had to be excluded because none of the 5 subjects who received the early-closure version of this sentence judged it to be grammatical. (4 of the 5 subjects who received the late-closure version of this sentence judged it to be grammatical, and thus responses to E3 also provide support for Late Closure.)

As a control measure, 7 (different) subjects were asked to rate the naturalness of the experimental sentences. The overall naturalness ratings were nearly identical for early-closure, late-closure and semantic-control sentences.

I take the results of this experiment to strongly support the conclusion that Late Closure governs clausal assignment in sentences with temporarily ambiguous clause boundaries. This finding is of particular interest given that Late Closure presupposes some knowledge of the internal

structure of a clause. That is, the internal structure of the clause currently being parsed determines whether incoming material can be part of that clause. Whether or not a NP, infinitival VP, or some other constituent can legitimately be analyzed as belonging to a preceding or following clause depends on the subcategorization of the verbs in the sentence and the nature of the other constituents which have been assigned to the clause. Thus, at least in sentences with temporarily ambiguous clause boundaries, it appears that analysis of the internal structure of a clause must precede clausal segmentation.

Returning to more general issues, I would like to extend this conclusion by suggesting that the parser may always proceed with the computation of the internal structure of a clause regardless of whether clausal segmentation has already been established. The fact that the parser does not know in advance whether the sentence it is parsing will contain only explicitly marked clause boundaries, and thus does not know in advance whether or not it will have to rely on Late Closure for clausal assignment suggests that it would be uneconomical for the parser to delay computation of the internal structure of a clause, especially given that the internal structure of a clause must be computed at some stage of the parsing process in any case. Thus, only an extremely inefficient parser would ignore useful information about sub-clausal constituents and merely wait for a grammatical marker which may or may not occur.

In fact, even if it is true that the parser makes use of grammatical markers when they do occur, this does not entail the further assumption that the parser delays analysis of sub-clausal constituents. The facilitating effect of grammatical markers which signal clause boundaries can be explained apart from this

further assumption, on the basis of two facts. First, grammatical markers prevent temporary ambiguity with respect to clause boundaries and thus we would expect them to facilitate parsing. Secondly, grammatical markers need only be identified in order to function as unambiguous clause markers, whereas other signals of clause boundaries - such as 'fell' in (7a) - require a certain amount of analysis before they can be interpreted as a signal of a clause boundary. Thus, in (7a) 'fell' does not signal the end of a clause until the parser has determined that 'fell' can not be part of the VP dominating 'kicked'.

Furthermore, if it were true, as suggested by the clause-first model of sentence perception, that clausal segmentation precedes analysis of the internal structure of a clause, we might expect the language to be designed to suit this purpose(within the constraints imposed by universal grammar). But, the structure of English, at least, does <u>not</u> facilitate clause-first parsing. It is true that the beginning of a subordinate clause is sometimes marked by the occurrence of a complementizer, relativizer or subordinator, but the beginnings of main clauses have no characteristic markers, nor do the ends of any clauses. Also, of course, the unmarked beginning of a new clause need not coincide with the end of the previous clause, as we might have expected if the language were accomodating a parser concerned with early clausal segmentation.

Moreover, it is a quite remarkable fact that English allows deletion of grammatical markers which signal clause boundaries. Notice that other grammatical markers, such as those indicating number and person on verbs, are <u>not</u> deletable, even though the information they carry is typically redundant and less crucial to the structural decoding of the senterce. Thus, the design of English does not appear to accommodate in any way whatsoever a

parser which depends on early clausal segmentation for purposes of later computations.

To summarize, I have argued that Late Closure governs clause boundary assignment, at least in those sentences where clause boundaries are not explicitly marked. Because Late Closure relies on information about the internal structure of a clause, this entails that at least in some cases the parser must compute the internal structure of a clause before segmentation of that clause has been established. I have also suggested, contrary to the clause-first model of sentence perception, that the design of English and the fact that the parser does not know in advance whether it will encounter only explicitly marked clause boundaries suggest that the parser may always proceed with the analysis of sub-clausal constituents regardless of whether clausal segmentation has been established. This suggests that the parser's operations may be more rigidly sequenced by the string of words it is receiving than is indicated in the rather active and free-wheeling model of Fodor, Bever and Garrett.

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